SIMULATION FOR POSITION CONTROL OF DC MOTOR USING FUZZY LOGIC CONTROLLER

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A project report submitted in partial
fulfilment of the requirement for the award of the
Degree of Master of Electrical Engineering

Faculty of Electrical and Electronics Engineering
Universiti Tun Hussein Onn Malaysia

JULY 2013

DEDICATION

Special dedication to my beloved family,
Ali Bin Jusoh & Noryati Bt Mohd Nor (Parent) and all family members,
lectures and friends who have encouraged and inspired me. Thanks for all the support.
May Allah bless all of you

ACKNOWLEDGEMENT

Alhamdulillah to Allah SWT the Most Beneficent and the Most Merciful, with the deepest sense of gratitude of the Almighty that gives the strength and ability to complete this final year project. All praise to Allah.

First and foremost, I would like to express my sincere appreciation to my supervisor, Dr. Wahyu Mulyo Utomo for the help and support given throughout the duration for this project, the lecturer who devotedly his time helping and contribute precious ideas and constant guidance and his willingness in sharing knowledge towards the completion of this thesis.

A special thanks to my beloved family especially my parent, Ali Bin Jusoh and Noryati Bt Mohd Nor, siblings and friends for their love support and motivation for me to pursue my studies. Thank you for the encouragement.

Last but not least, I would like to extend my gratitude to all friends, colleagues and who helped me directly or indirectly for their encouragement and help. Thank you very much and may Allah bless you.

ABSTRACT

The purpose of this project is to control the position of DC Motor by using Fuzzy Logic Controller (FLC) with MATLAB application. The scopes includes the simulation and modelling of DC motor, fuzzy controller and conventional PID controller as benchmark to the performance of fuzzy system. The position control is an adaptation of Closed Circuit Television (CCTV) system. Fuzzy Logic control can play important role because knowledge based design rules can be easily implemented in the system with unknown structure and it is going to be popular since the control design strategy is simple and practical. This make FLC an alternative method to the conventional PID control method used in nonlinear industrial system. The results obtained from FLC are compared with PID control for the dynamic response of the closed loop system. Parameters such as peak position in degree, settling time in second and maximum overshoot in percent will be part of the simulation result. Overall performance show that FLC perform better than PID controller.

ABSTRACT

Tujuan projek ini dilaksanakan adalah untuk pengawalan posisi *DC motor* dengan menggunakan *Fuzzy Logic Controller* (FLC) dengan menggunakan aplikasi MATLAB. Skop kajian merangkumi simulasi dan model *DC motor*, kawalan *Fuzzy* dan kaedah lama iaitu dengan menggunakan kawalan *PID* sebagai garis pengukur bagi menentukan prestasi dalam sistem *fuzzy*. Kawalan posisi ini adalah adaptasi kepada sistem litar tertutup (CCTV). *Fuzzy Logic control* memainkan peranan penting kerana pengetahuan asas dalam peraturan rekaannya boleh dikatakan mudah untuk digunapakai dalam sesuatu sistem, di mana strukturnya tidak dikenal dan ianya akan menjadi popular kerana kawalan rekaannya adalah mudah dan praktikal. Ini akan membuatkan *FLC* sebagai satu cara alternatif kepada cara lama iaitu kawalan *PID* yang digunakan di dalam sistem industri yang tidak linear. Keputusan yang diperolehi dari *FLC* dibandingkan dengan kawalan *PID* untuk respon yang lebih dinamik dalam litar tertutup. Parameter seperti posisi paling puncak dalam darjah, masa stabil dalam unit saat dan juga kenaikan melebihi posisi yang ditetapkan dalam peratusan. Ini semua akan menjadi sebahagian dari keputusan simulasi. Secara keseluruhannya prestasi menunjukkan bahawa kawalan *FLC* adalah lebih baik dari kawalan PID.

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LIST OF ABBREVIATIONS AND SYMBOLS

DC	-	Direct Current
PWM	-	Pulse Width Modulation
PID	-	Proportional Integral Derivative
FLC	-	Fuzzy Logic Controller
FC	-	Fuzzy Controller
CCTV	-	Closed Circuit Television
PAN	-	Horizontal adjustment
TILT	-	Vertical adjustment
M_P	-	Peak overshoot
e_{SS}	-	Steady state error
t_s	-	Settling time
t_r	-	Rise time
t_p	-	Peak time
$I_a(t)$	-	Motor current
V_a	-	Armature Voltage
R_a	-	Armature resistance
L_a	-	Armature inductance
T_m	-	Motor torque
J_m	-	Motor inertia
B_m	-	Damping ratio / Viscous friction coefficient
K_m	-	Torque constant
K_B	-	Back EMF constant
θ	-	Angular speed
ω	-	Speed

K_p	-	Proportional gain
K_i	-	Integral gain
K_d	-	Derivative gain
K_u	-	Ultimate gain
T_u	-	Ultimate time
T_I	-	Integral time
T_p	-	Peak time
T_D	-	Derivative time
u(t)	-	Control signal
OS%	-	Percentage of Overshoot

CHAPTER 1

INTRODUCTION

1.1 Project overview

An electric motor is an electric machine that converts electrical energy into mechanical energy. Electric motor can be powered by Direct Current (DC) sources such as batteries, motor vehicles or rectifiers ,or by and Alternating Current (AC) sources, such as from power grid, inverters, or generators.

In this thesis, DC motor have been selected because it is widely used in industrial applications, robot manipulators and home appliances where speed and position control are required. The dc motors can comes in many shapes and sizes, makes the development of dc motor application quite easy and flexible.It is also has high reliabilities and low cost.[1]

The scope of this project is to mimic the position control of Closed-circuit Television (CCTV). The starting point for any CCTV system must be the camera. The camera creates the picture that will be transmitted to the control position. A movable camera may be placed on a platform that may be controllable in both horizontal and vertical planes and it is generally known as PAN where it is the ability to sweep left to right (horizontally) and TILT where it is the ability to move up and down (vertical) movement. The vertical movement start from 0 to 90 degree while for horizontal movement the range is from 0 to 360 degree. Each movement can be done one by one at a time.

Many types of conventional control schemes, such as Proportional-Integral (PI), Proportional-Integral-Derivative (PID), optimal, adaptive and robust controllers have been developed to reduce load effects. Although each approach has its advantages and disadvantages in practical realization, most controllers still have to be designed on the basis of the parameters and the detailed structure of the plant. Failing this, better control performance will not be obtained as load effects occur. Therefore, this work develops a control structure to eliminate heavy and / or unbalanced load effects.[2]

In control systems, fuzzy logic is considered as an alternative for conventional control theory in the control of complex nonlinear plants where precise mathematical modelling is difficult or impossible [3].

The main advantage of fuzzy logic as compared to conventional control approach resides in the fact that no mathematical modelling is required for the design of the controller. The control rules are based essentially on the knowledge of the system behaviour and the experience of the control engineer. Since the fuzzy logic controller requires less complex mathematical operations than classical controllers, its implementation does not require very high speed processors.

Both controllers mentioned above will be using Pulse Width Modulation (PWM) as it is the most frequently consider method among the various switching control method (J. Alvarez-Ramirez, Jan. 2001) .This controller often applied to the converters because of their simplicity.

In this project, MATLAB/Simulink is used as a platform in designing the fuzzy logic controller. Simulation of PID controller also included in this thesis as a comparison in terms of its performance.

1.2 Problem statement

An attempt to carry out the control of a system applying the classical control theory, mathematical model is needed for the process and information about the evolution of the system variables to close the control loops. Normally both conditions are difficult to resolve: sometimes because of the complexity of the process or lack of knowledge we have about it, and other times because of the insufficient technological level reached at the moment in the sensor field. New process control techniques now combine advances in computer hardware and sensors with new programming techniques. In this way they attempt to solve difficult control problems [4].

PID controller can perform very well but somehow not adaptive enough to support different possibility occurred. This is appealing when the load is changed, where the original controller generally cannot maintain the design performance and thus should be re-designed for the new system conditions. Therefore, fuzzy logic controller can be implemented due to its good robustness. However the implementation require experience and skill and the response is a bit slower than conventional controller.

The pioneering work dealing with expert knowledge that can be well applied to the control of systems with uncertained, nonlinear dynamics is credited to Zadeh (Zadeh, 1968) who proposed fuzzy control theory to overcome the weakness of conventional controllers. Fuzzy systems are capable of handling complex, non-linear and sometimes mathematically intangible dynamic systems using simple solutions. Fuzzy logic uses human-like but systematic properties of converting linguistic control rules based on expert knowledge into automatic control strategies [5].

1.3 Project Objectives

This project are performed to study the characteristic of DC motor by conducting simulations of a DC motor using Fuzzy Logic controller systems for position control. The objectives are as follows:

i. To built a modeling simulation for DC motor using MATLAB/Simulink.
ii. To simulate position control of DC motor using Fuzzy Logic Controller (FLC).
iii. To simulate position control of DC motor using conventional controller (PID) as a comparison to FLC in the same range.

1.4 Project Scope

The scopes of this project are described as follows:

i. Simulation of DC motor controller using MATLAB/Simulink.
ii. Simulation for position control using fuzzy logic controller and conventional controllers will range up from 0 to 360 degree.
iii. Implementation of fuzzy logic controller in controlling the position of the DC motor adaptation of Closed Circuit Television (CCTV) application.
iv. The analysis of both controllers involved with peak overshoot and settling time.

1.5 Project report Layout

In chapter one (Chapter 1) , the project overview, problem statement, project objective and project scope that relates with position control of DC motor using fuzzy logic controller have been discussed.

In second chapter (Chapter 2), all the literature review from the previous study related to the objectives of the study had been gathered. This includes conventional controller as the comparison to fuzzy logic controller.

In third chapter (Chapter 3), the overall design and methods to apply in this study had been stated. The main methodology that been stressed out related position control of DC motor using fuzzy logic controller and PID controllers.

In forth chapter (Chapter 4), consist of expected outcomes that been stated based on the objectives of the study. It shows that by using fuzzy logic controller the position controller of DC motor can be simulated.

In last chapter (Chapter 5), is the conclusion and recommendation for future study. References cited and supporting appendices are given at the end of this project report.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Electric motors are standardized versions for general-purpose applications. Other electric motors are intended for specific tasks. In any case, electric motors should be selected to satisfy the dynamic requirements of the machines on which they are applied without exceeding rated electric motor temperature. Thus, the first and most important step in electric motor selection is determining load characteristics. Electric Motor selection is also based on mission goals, power available, and cost.

2.2 Existing Model

There are many papers about DC motor fuzzy control system design. Lin et. al. compared PID and FLC for position control and observed that FLC performed better than PID (Lin 1994). Azevedo et. al. have shown that FLC is less sensitive than PID to load variations (Azevedo,1993) Bal et.al. designed an FLC for an ultrasonic motor which has different operation principle than electromagnetic motors (Bal.2004). Mishra et. al. made a comparison between PID and FLC for servomotor control and described that PID parameters had to be tuned again under variations of plant parameters or noise wherever FLC parameters had not (Mishra,1998). Kwon et. al. designed a PI controller for a brushless DC motor and built an adaptive fuzzy tuning system to modify the controller parameters under load variations during operation (Kwon,2003). M.H. Zadeh et.al. explained that one of the best methods for control of DC motor with time-varying parameters was fuzzy sliding mode control (Zadeh, 2006)[1]

The authors in [6] made a comparison between proportional control and fuzzy control on a laser beam alignment system. It was shown that the fuzzy controller significantly reduced the overshoot and virtually eliminated limit cycling.

Li and Lau [7] investigated the possibility of applying fuzzy algorithm in a microprocessor-based servomotor controller, which requires faster and more accurate response compared with other industrial processes. A set of simulation results on the performance of PI control, model reference adaptive control and fuzzy controllers are compared in terms of steady-state error, settling time and response time. According to the simulation results, the settling time of the fuzzy controller is only two-fifths that of PI controller.

Smith and comer [8] compared a fuzzy position controller with a PD controller using only the simulation result. The PD controller was tuned to minimize rise time with less than 5% overshoot. it was claimed that fuzzy controller is better than the PD controller.

Paul and John Chou [9] examine the application of real-time reasoning fuzzy controller and digital PID control algorithm to a PC based dc motor position controller. The specification for PC-based position controller including system hardware and software. the experimental study reveals that using FLC control to the position control application, shorter settling time can be achieved by tuning the control rules, membership functions and universe of discourse of the output variable. Comparison of experimental results of the PID and FLC position controllers show that the FLC controller is able to perform better than PID controller.

2.3 Introduction to DC Motor

A common actuator in control systems is the DC motor. It directly provides rotary motion and coupled with wheels or drums and cables, can provide translational motion.

2.3.1 Physical system

Consider a DC motor, whose electric circuit of the armature and free-body diagram of the rotor are shown in figure 2.1.

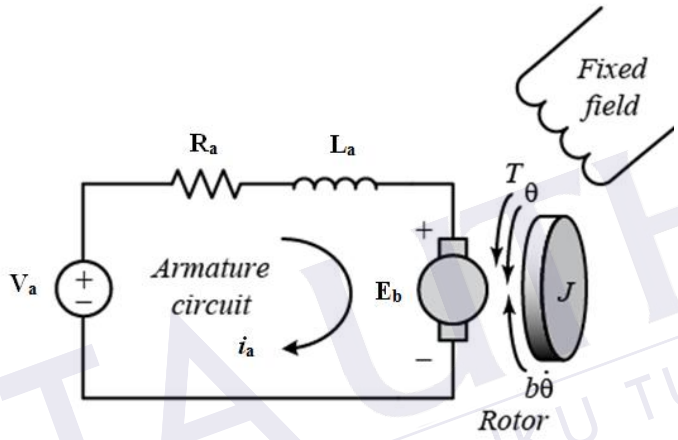

Figure 2.1 : Schematic representation of the considered DC motor

The input is the armature voltage V in Volts (driven by a voltage source). Measured variables are the angular velocity of the shaft ω in radian per second, and the shaft angle θ in radian.

Where:

V_a = armature voltage (V)

R_a = armature resistance (Ω)

L_a = armature inductance (H)

i_a = armature current (A)

E_b= back emf (V)

T = Torque (Nm)

θ = angular position of rotor shaft (rad)

2.3.2 System Equations

In armature control of separately excited DC motor, the voltage applied to the armature of the motor is adjusted without changing the voltage applied to the field where the output voltage and motor torque is relate to the equation below:

$$V_a(t) = R_a i_a(t) + L_a \frac{di_a(t)}{dt} + Eb(t) \qquad (2.1)$$

The motor torque, *T*, is related to the armature current *i*, by a constant factor *K*:

$$T = Ki \qquad (2.2)$$

The back electromotive force (emf),e_b is related to the angular velocity by:

$$E_b = K\omega = K\frac{d\theta}{dt} \qquad (2.3)$$

From figure 2.1, the following equations based on the Newton's law combined with the Kirchhoff's law can be write as:

$$J\frac{d^2\theta}{dt^2} + b\frac{d\theta}{dt} = Ki \qquad (2.4)$$

$$L\frac{di}{dt} + Ri = V - K\frac{d\theta}{dt} \qquad (2.5)$$

2.3.3 Transfer Function

Using the Laplace transform, equations (2.4) and (2.5) can be written as:

$$Js^2\theta(s) + bs\theta(s) = KI(s) \qquad (2.6)$$

$$LsI(s) + RI(s) = V(s) - Ks\theta(s) \qquad (2.7)$$

where s denotes the Laplace operator. From (2.7) we can express I(s):

$$I(s) = \frac{V(s) - Ks\theta(s)}{R + Ls} \qquad (2.8)$$

and substitute it in (2.6) to obtain:

$$Js^2\theta(s) + bs\theta(s) = K\frac{V(s) - Ks\theta(s)}{R + Ls} \qquad (2.9)$$

The equation for the DC motor is shown in the block diagram in Figure 2.2.

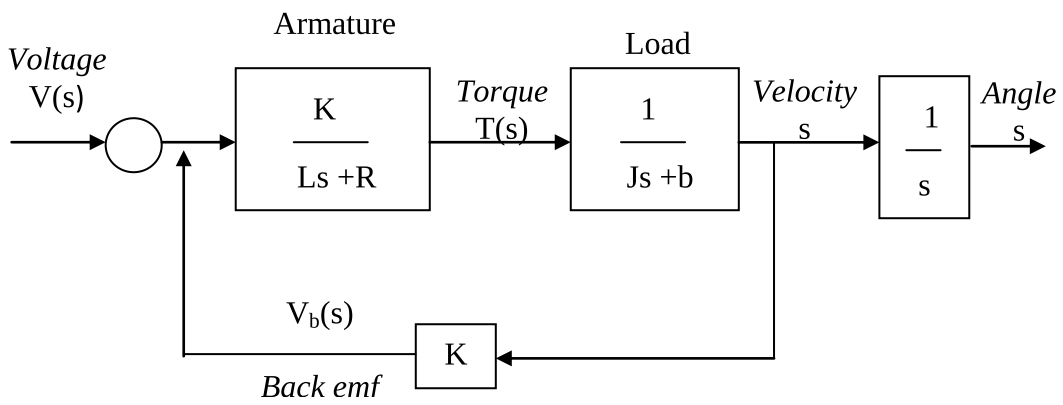

Figure 2.2 : A block diagram of the DC motor

From equation (2.9), the transfer function from the input voltage, V(s), to the output angle, θ, directly follows:

$$G_a(s) = \frac{\theta(s)}{V(s)} = \frac{K}{s\left[(R+Ls)(Js+b)+K^2\right]} \qquad (3.0)$$

From the block diagram in Figure 2, it is easy to see that the transfer function from the input voltage, V(s), to the angular velocity, ω is:

$$G_v(s) = \frac{\omega(s)}{V(s)} = \frac{K}{\left[(R+Ls)(Js+b)+K^2\right]} \qquad (3.1)$$

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